Two-Dimensional Xenes: Synthesis, Processing, and Manipulation

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Isolation of graphene paves the way to a new and unprecedentedly rich fashion of two-dimensional (2D) materials. While many of them are naturally available in the form of exfoliable single-crystal flakes, others can be artificially derived by synthetic approaches and their atomistic features tailored by design. Xenes, namely 2D single-element materials beyond graphene, are a representative case in this respect [1]. Xenes expand the graphene potential and constitute an emerging nanomaterials platform with potential for quantum nanoelectronics, spintronics, and topological application [2].
Here we will present a taxonomy of the Xenes with element X spanning from the IV column of the periodic table (e.g. silicene), to the adjacent columns (e.g. borophene, phosphorene, tellurene, etc.) [3]. In detail, we will describe how Xenes are mainly produced by bottom-up approaches to 2D crystal epitaxy including the direct deposition, the top-to-bottom intercalation through an interface layer, and the bottom-to-top segregation. We will take silicene, epitaxial phosphorene, and tellurene as a paradigmatic case to elucidate the different growth methodologies within the epitaxial deposition scheme and to stress out the configurational constraints in the Xene growth. In parallel, we will consider the topotactic deintercalation of silicon as an example of a top-down approach to selected Xene production. We will show to what extent Xenes can be massively produced up to the large-area [4], how they should be stabilized to further up the integration into transistor device structures [5], and what benefits can be derived from multiple Xene combinations inside epitaxial Xene heterostructures [6].
In the end, we will briefly describe methods to reduce Xene in transferable and bendable foils to be used both in solid-state and flexible platforms.
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References

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